PHASE SHIFTS

The harmonics lead the fundamental.

by Merlijn van Veen

"It turns out that, within very generous tolerances, humans are insensitive to phase shifts. Under carefully contrived circumstances, special signals auditioned in anechoic conditions, or through headphones, people have heard slight differences. However, even these limited results have failed to provide clear evidence of a "preference" for a lack of phase shift. When auditioned in real rooms, these differences disappear…" ***—Dr. Floyd Toole***

As Dr. Toole states, a lot of people, including myself, have a hard time detecting phase shift (not to be mistaken with phase offset). In experimenting with this issue and documenting it on a video that can be viewed on my website as well as ProSoundWeb, I applied gratuitous amounts of phase shift to a music track by means of all-pass filters.

After demonstrating that the plugins were actually doing something, it was difficult to hear any differences but for the occasional pop and dropout of my computer trying to cope. At the end of the experiment, when I switched over from phase to group delay, as much as 15 milliseconds (ms) of frequency-dependent "time smearing" was introduced. And that's on top of the inherent phase shift of the loudspeakers or headphones used to listen to the sound of the video.

A couple of people I hold in high regard, Mauricio "Magu" Ramírez of Meyer Sound and François "Frankie" Desjardins of Solotech (among others), have heard actual loudspeakers with linear "flat" phase behavior from virtually DC to light. Doing blind A/B testing with their favorite tracks, they initially detected no differences between linear phase and minimum phase (typical behavior for real-world loudspeakers) responses. But when a track contained substantial low-frequency information (e.g., bass guitar, drums, or deep vocals), they immediately noticed a difference that can be best described, from what I came to understand, as presence. Where these instruments or voices previously sounded ambiguous, now they suddenly were up close and personal, with focus and impact.

This raised the question as to what causes this sensation. The only explanation I can think of, and it probably isn't novel, is that in a typical sound system, for low-frequency sources, the harmonics lead the fundamental. The fundamental allows us to detect pitch and the harmonics (multiples of the fundamental frequency) enable us to distinguish violin from clarinet or Willie Nelson from Leonard Cohen. Without harmonics, all sources would be producing sine waves exclusively and thus be indistinguishable from each other.

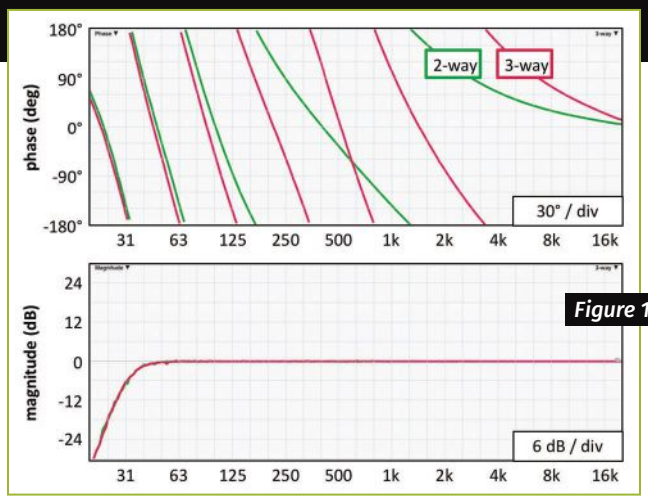

Figure 1

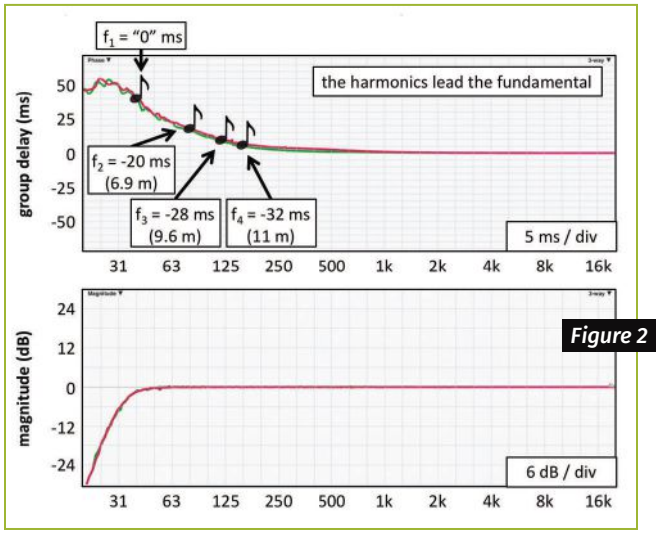

Figure 2

Figure 1 shows the typical phase shift for a regular (no FIR or all-pass filters) 2-way or 3-way loudspeaker, complemented with a non-overlapping, phase-aligned (ported) subwoofer. All crossovers consist of 4th-order Linkwitz-Riley filters at unity gain. **Figure 2** tells the same story but now instead of phase, group delay is shown.

In the case of the lowest open E-string on a typical bass guitar with a fundamental frequency of 40 Hz, the 2nd, 3rd and 4th harmonics lead by 20, 28 and 32 ms, respectively. That's 7 to 11 meters! If we nullify this phase shift, I would expect to hear a difference. Having the harmonics delivered simultaneously with the fundamental instead of in series produces steeper, more transient edges in the waveform that tightens and cleans up the sound.

Flattening the phase can be done, e.g., with FIR filters, in exchange for latency. The duration of the Finite Impulse Response filter needs to be at least twice the period duration of the lowest frequency it's describing. That's 100 ms at 20 Hz! Unacceptable for live sound reinforcement but not for playback situations.

I, for one, am hoping to experience it myself one day. LSI

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